and St. Augustine forms are almost devoid of this character. The material from which Conrad described his species probably came from the west coast of Florida in the vicinity of Tampa. Forms of *T. floridana* from this region differ from East Florida and Texas forms in being slightly narrower.

The main characters of *T. floridana haysae* are very constant, with the exception of the proportionate length of the spire as exhibited by the type series. One specimen is very much longer than any of the others (112.5 mm.), though its other measurements are more or less consistent. The two- and three-ridged tubercles are produced by an increased size of the spiral ridges as they pass over these formations.

Miss Hays reports that this form does considerable damage to the oysters in the delta region and is known locally as the "drill", a name applied as well to *Urosalpinx cinereus* Say.

A QUANTITATIVE STUDY OF THE MARINE MOLLUSKS OF CAPE MAY COUNTY, NEW JERSEY

BY ALBERT ELMER WOOD AND HORACE ELMER WOOD 2ND

The plan of this paper was developed by the junior author following a conversation with the late Professor Gilbert Van Ingen of Princeton University on the need for an ecological study of the South Jersey sounds facies before the region was too thoroughly "improved" with summer resorts. This region has not been studied ecologically. However, it does not differ fundamentally from the Wood's Hole Region, which has been studied intensively; and scattered work has been done as far south as Beesley's Point, the extreme northern tip of Cape May County. Davenport's

classical study of the Cold Spring sand spit gives much the closest analogy, in miniature, to Seven Mile Beach, a fairly typical South Jersey barrier island. The inner harbor, cut off by the sand spit from the outer harbor, makes a situation very similar to the sounds, separated from the ocean by the island.

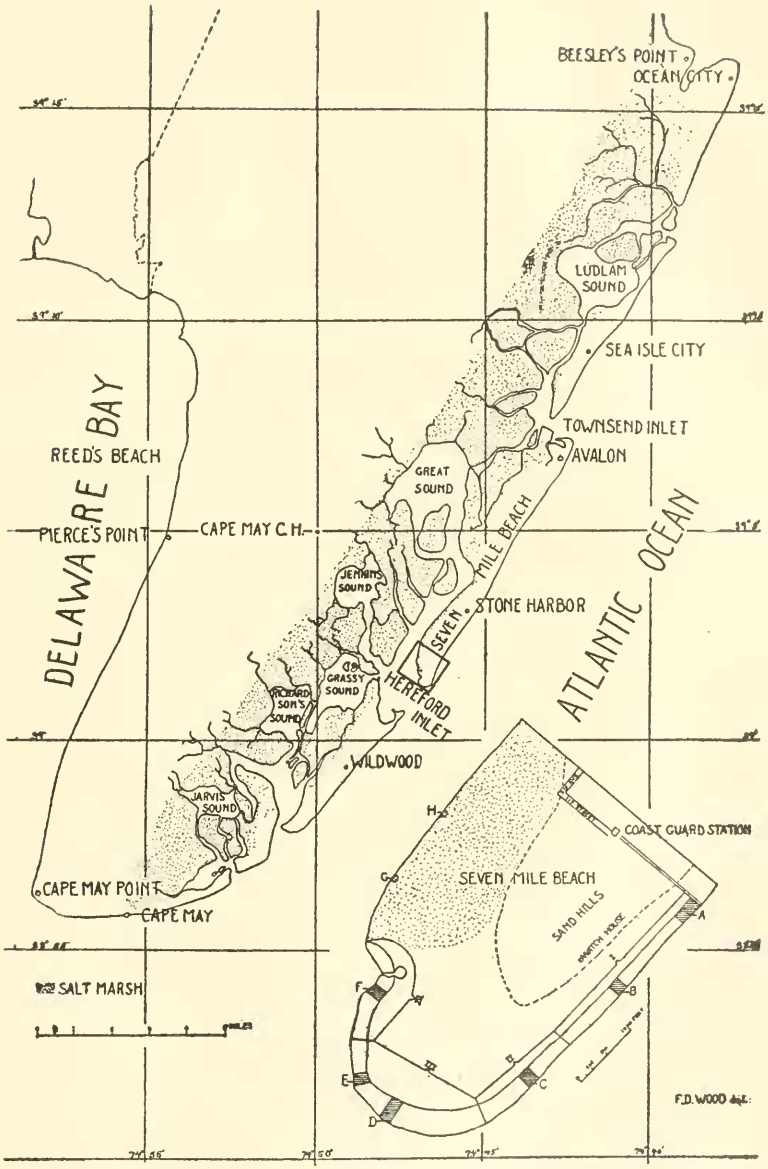
There are no pretensions to new systematic data in this paper, nor are the ecological results particularly striking. The use of large enough numbers to give statistical validity and the stratigraphic implications are perhaps more significant. It seems possible that some such quantitative differences in the proportions of various forms or groups as are recorded in table 1, may be found to hold good, in a general way, throughout the Cenozoic, since most existing molluscan genera go back about that far. Not only the list of species present in a given formation, but also the relative abundance of individuals of the various species should be taken into account in determining what facies is represented. Stratigraphers could make use of the data of ecology, particularly quantitative ecology, to great advantage. This paper is only a suggestion as to the possibility of deriving advantage from this line of attack, in dealing with stratigraphic and paleogeographic problems.

Studies somewhat similar in subject matter are those of: Allee (1923 *a* & *b*), Davenport (1903), Packard (1918), Sumner, Osborn and Cole (1911) and Verrill (1873). The bearing of ecology on stratigraphy is implied by H. B. Baker (1914) and emphasized by F. C. Baker (1922), both, however, in relation to epicontinental forms. The importance of quantitative ecology is emphasized by Forbes (1907), Packard (1918) and Michael (1920). The closest parallel to this paper is by Abrard (1924), in which he undertook, with the tertiary stratigrapher in mind, a qualitative study of variations in molluscan shells cast up at intervals along the west coast of France, finding intergradations between typical marine and estuarine faunules. His point of view is very similar to this study, and there are certain slight similarities in results.

The field work was done by the senior author with the assistance of the junior author, Messrs. George Clark, John Clark, and Blair Wood. The counts were made during the summers of 1924 and 1926. All the localities selected were those least "favored" by summer visitors, and the southern end of Seven Mile Beach is almost unaffected by human activities. The specific identifications should be accepted with some slight reserve as the authors are not specialists in this field, and the nomenclature is subject to the same reservation. The scope of the study was limited to the area between high and low water marks, although, obviously, most of its mollusk shells are cast up from the submerged zone. Where a very abundant animal was counted in a small area, this area was selected where the animal in question was especially numerous, as giving an approach to its maximum frequency. Shells were not counted unless more than half intact. Allowance must be made for the prevalence of pelecypod valves over gastropods, as 2:1, given the same number of individuals, for the greater fragility of some forms, producing a fictitious rarity, and for the tendency to overlook small specimens. All these factors, of course, affect fossil faunas equally. One special factor, in this case, is the strong tidal current which sweeps in and out of Hereford Inlet, and brings many empty shells into facies in which they are never found alive.

There is the usual sand hill sequence; bunch grass, then bay-berry (here growing to be real trees over ten feet high), wild cherry later, and finally scrub cedar, which formerly ran the whole length of the island in a narrow belt. The newest sand hills are toward the ocean—one full row has developed during the last twelve years, under the observation of the authors.

Donax variabilis is found alive all along the beach, but especially north of Section III. *Busycon canaliculatum, B. caricum, Natica duplicata, N. heros* and *Mactra solidissima* live in the sand on the ocean side, often being exposed at low tide. *Mytilus edulis* inhabits mud banks in the outer channels, exposed at low water, and also piles in the open



Map of Cape May County, modified from those of the U. S. Geological Survey. The inset sketch map of the southern end of Seven Mile Beach was made for this paper, the distances being paced off.

ocean. *Nassa obsoleta* occurs in life in vast numbers throughout the lower regions of the outer channels, especially where there is about 50-50 admixture of mud and sand. *Mya arenaria* has nearly the same habitat as *Nassa*, except for the fact that when marsh grass over-runs the ground, *Mya* remains, but *Nassa* does not. *Mya* also extends further north in the channel than *Nassa* does. *Ensis directus* lives in mud or sandy mud in the outer channels, in the inter-tidal zone. *Venus mercenaria* and *Ostrea virginica* have habitats similar to *Ensis*, except that they inhabit slightly deeper water, and all the channels. *Modiola plicatula* occupies the banks of the channels. *Littorina litorea* clings to grass in salt marshes. The fauna of the minor sounds was not studied; in general its mollusks consist of a few species, i. e., *Venus mercenaria, Modiola plicatula, Littorina litorea, Ostrea virginica* and *Nassa obsoleta.*

Packard (1918) and Allee (1923 a) count living animals only, as the shells of dead animals may be distributed by currents, tides, shore birds and hermit crabs. In spite of the errors they introduce, empty shells are included in this count, for the following reasons: 1, the stratigrapher can not make such a distinction, even if the ecologist can; 2, the use of only living specimens reduces the total numbers to such a point that they are not statistically significant. Allee's figures suffer from this; Packard, however, counts empty shells separately.

Allee (1923 b) refers to "old associations" and "ecological age", following Cowles, Shelford and Adams, when, by all analogy and common sense, just the opposite is meant. By their terminology, the open ocean is ecologically the youngest and the recently formed sandy beach, the oldest. This is directly opposed to other uses of "old" and "young", both ordinary and scientific, and should be discontinued.

Pairs of attached pelecypod valves were counted separately, except in the case of *Donax* in A and B. Additional errors of proportion are introduced by including, without correction, the numbers of *Donax* in A and B, *Nassa* in F

and G and *Mytilus* in H, in smaller areas than for their competitors. The proportions that follow, taken without correction from table 1, therefore, tend to give minimal values. On the ocean side, pelecypod shells outnumber gastropods more than 46:1, or, allowing fully for the double pelecypod valves, they outnumber the gastropods more than 23:1. On the channel side, the gastropods are outnumbered by the pelecypods as 7:8, or, from the view-point of the number of animals, the gastropods are nearly twice as numerous in the sections counted, and the actual predominance of gastropods in the fauna is greater than the figures show. Making rough corrections for the various sources of error, it is safe to say that pelecypods are at least thirty times as numerous as gastropods on the open beach, and that gastrapods are definitely more numerous than pelecypods in the outer sounds. On the other hand, Packard (1918) found that, in San Francisco Bay, the pelecypods were nearly five times as numerous as the gastropods, but that the preponderance was much less marked just outside the Golden Gate. Much more work must be done before any definite generalizations can be made.

The localities on Seven Mile Beach, A to H inclusive (see map), represent a progressive transition from a typical ocean (beach) facies to a typical interior channel (sounds) facies. Localities A, B, and C are along the ocean, approaching the southern end of Seven Mile Beach. D is on the point itself, E and F are to the north, on a somewhat muddy beach on the channel side. G is a sandy tidal mud flat. H is a mussel bed on a sandy mud bar. Pierce's Point and Reed's Beach have narrow, steeply sloping sandy beaches with mud flats at the foot exposed only at low tide.

	1924		1926	
	Along Beach	Intertidal	Along Beach	Intertidal
Section A	300 feet	150 feet	300 feet	175 feet
Section B	150 feet	100 feet	150 feet	175 feet
Section C	150 feet	.....	150 feet	200 feet
Section D	150 feet	.....	150 feet	450 feet
Section E	150 feet	.....	150 feet	180 feet
Section F	150 feet	225 feet	150 feet	215 feet

Section G was one square yard, both years
Section H was six inches square, both years

A few specimens of the following shells were also present in I and II, but were not found in the sections which were counted:—*Buccinum undatum, Busycon perversum, Pholas costata, Sigaretus perspectivus,* and *Zirphaea crispata* (?).

The Pierce's Point area extends a hundred feet south from the second rail run-way south of the road across the marshes. The distance from high to low water mark is fifty feet (not counting the mud flats beyond, exposed only at dead low tide). Neither *Ostrea virginica* nor *Nassa obsoleta* nor *Melampus bidentatus* were counted from the whole section, but from small areas.

At Reed's Beach, the count started from fifteen hundred feet north of the road across the marshes, at a king-crab drying pen, and continued twenty five feet further on, and extended the ninety feet from high water mark to the edge of the mud flats which were covered at the time the area was visited. Most of the shells were concentrated in a strip about a foot wide at high water mark, to which strip the figures in table 1 apply. On the rest of the beach there were 83 shells of *Ostrea virginica* and the fragment of a *Venus mercenaria.*

Table 1 gives the complete figures for the various areas in which the shells were counted. Table 2 is a qualitative summary of table 1.

TABLE ONE

GASTROPODS	Sect. A		Sect. B		Sect. C		Sect. D		Sect. E		Sect. F		Sect. G		Sect. H		Pierce's Reed's	
	1924	1926	1924	1926	1924	1926	1924	1926	1924	1926	1924	1926	1924	1926	1924	1926	1924	1926
Busycon canaliculatum										2		2					2	
Busycon caricum	2	1	1			1		5	6	20		8					1	2
Crepidula convexa						1	1	10	2	11	2	1					22	9
Crepidula fornicata	16	14	12	3	1	25	11	20	1	13	3	23					20	3
Crepidula plana	27	10	5	8	2	24	1	10	5	14		4					1	1
Littorina litorea					2				1	4		3						
Melampus bidentatus								1		6		3					h	2
Nassa obsoleta		1		1		3			818	1179	f	g	1305	1493			i	171
Nassa trivittata								2	7	9	8	125		2			19	12
Natica duplicata	2		8	3		1	2	3	5	17	4	16					1	
Natica heros	2		1			1		1	1	4		4					4	
Scalaria lineata																		1
Urosalpinx cinereus				1				1		2	1	3					4	4
PELECYPODS																		
Anomia glabra	612	915	503	462	158	750	291	491	12	244	54	72		1				
Arca pexata	29	2	6	8	1	17		10	5	2		2					1	
Arca ponderosa		1	4		1	2	2		1	3		2						
Arca transversa		4	3	2		11	2	5	1	4	2	4						
Donax variabilis	b	c	b	d	b	e	b	339	398	369	193	279					18	
Ensis directus a	18	33	3	8	2	19	24	18	21	7	2	12					72	
Lucina dentata	15	4	9	10	4	15	5	5		6								
Macoma baltica																	371	336
Mactra lateralis																	350	318
Mactra solidissima a	521	465	806	229	44	971	223	784	209	938	94	248		4				
Modiola plicatula	2	4	1		1		3	5	1	12	3	6				5	42	1
Mya arenaria		1				1				1	1						13	
Mytilus edulis	84	381	142	59	42	128	93	115	36	51	123	75		10	503	182	7	4
Ostrea virginica	215	104	80	42	26	82	87	118	40	241	35	124			6	2	j	582
Pandora trilineata	5	4	2	1	1	3		1										
Pecten irradians	22	35	42	7	22	48	14	20	6	14	5	7		1				
Petricola pholadiformis	3	9	4	3	5	5	6	19	3	1	6	2				17	2	
Tagelus gibbus	2	4	2	1	2	6	3	4	2	4								
Tellina tenta								2									6	
Venus mercenaria	7	8	3	1	2	7	6	2		17	1	3		6			4	

a. Fauna of a tide water pool in section B, i. e., 6 **Mactra solidissima** and 4 **Ensis directus**, omitted in the list. b. Count omitted in 1924. c. Count omitted in 1926. d. 1510 live **Donax variabilis** counted in one square foot. e. 47 live **Donax variabilis** counted in one square foot. f. 2842 live **Nassa obsoleta** were counted in an area 82.5 feet by 225 feet. g. 1586 live **Nassa obsoleta** were counted in an area 87 feet by 60 feet. h. 58 **Melampus bidentatus** were found in four square feet. i. 89 live **Nassa obsoleta** were found in four square feet. j. 76 **Ostrea virginica** were counted in four square feet. Only the adults were listed. There were several times as many young ones attached.

TABLE TWO

Dominant Molluscs (in the order of their relative abundance).

Section A.		Section B.		Section C.	
1924	1926	1924	1926	1924	1926
Donax	Donax	Donax	Donax	Donax	Donax
Anomia	Anomia	Mactra	Anomia	Anomia	Mactra
Mactra	Mactra	Anomia	Mactra	Mactra	Anomia
Ostrea	Mytilus	Mytilus	Mytilus	Mytilus	Mytilus
Mytilus	Ostrea	Ostrea	Ostrea	Ostrea	Ostrea
		Pecten		Pecten	Pecten

Section D.		Section E.		Section F.	
1924	1926	1924	1926	1924	1926
Anomia	Mactra	N. obsoleta	N. obsoleta	N. obsoleta	N. obsoleta
Mactra	Anomia	Donax	Mactra	Donax	Donax
Donax	Donax	Mactra	Donax	Mytilus	Mactra
Mytilus	Ostrea	Ostrea	Anomia	Mactra	Ostrea
Ostrea	Mytilus	Mytilus	Ostrea	Anomia	N. trivittata
			Mytilus	Ostrea	Mytilus
					Anomia

Section G.		Section H.	
1924	1926	1924	1926
N. obsoleta	N. obsoleta	Mytilus	Mytilus

Pierce's Point
1924
Ostrea
Nassa obsoleta
Melampus
Macoma
Mactra lateralis
Ensis

Reed's Beach
1926
Ostrea
Macoma
Melampus
Nassa obsoleta

It is noteworthy that the counts for the two summers, 1924 and 1926, run closely parallel as to relative frequency at least of the more abundant shells, and run roughly parallel as to the numbers themselves.

SUMMARY

1. Ecology, and particularly statistical ecology, may be of great assistance in solving stratigraphic problems.

2. For statistical treatment, sufficiently large numbers must be obtained to make the results significant. In deal-

ing with mollusks, this usually involves including the shells of dead individuals in spite of the errors introduced. The stratigrapher must deal with such material.

3. The counts for the summers of 1924 and 1926 run roughly parallel as to the more abundant species.

4. On the open ocean beaches of Cape May County, New Jersey, pelecypods enormously outnumber gastropods. In the main sounds, gastropods are the dominant element.

5. Collections along the ocean beach are marked by *Donax, Anomia, Mactra, Mytilus,* and *Ostrea;* in the outer sounds by *Nassa obsoleta* and *Modiola* as well; from Delaware bay by *Ostrea, Nassa obsoleta, Melampus* and *Macoma.*

REFERENCES

Abrard, R. 1924. Note sur les dépôts littoraux entre l'embouchure de la Seudre et celle de la Gironde. Bull. Mus. Nation. d'Hist. Natur., Paris, XXX, p. 536-542.

Allee, W. C. 1919. Note on animal distribution following a hard winter. Biol. Bul., XXXVI, p. 96-104.

1922. The effect of temperature in limiting the geographical range of invertebrates in the Wood's Hole littoral. Anat. Rec., XXIII, p. 111.

1923a. Studies in marine ecology: I. The distribution of common littoral invertebrates of the Wood's Hole Region. Biol. Bul., XLIV, p. 167-191.

1923b. Studies in marine ecology: III. Some physical factors related to the distribution of littoral invertebrates. Biol. Bul., XLIV, p. 205-253.

Baker, F. C. 1922. The importance of ecology in the interpretation of fossil faunas. Ecology, II, p. 277-280 (for "Oct. 1921"). Jan. 20, 1922.

Baker, H. B. 1914. Physiographic and molluscan succession in lake pools. Rep. Mich. Acad. Sci. XVI, p. 18-45.

Davenport, C. B. 1903. The animal ecology of the Cold

Spring sand spit. Decennial Publ. Univ. Chicago, X, p. 157-176.

Flattely, F. W. and Walton, C. L. 1922. The biology of the sea-shore. MacMillan, N. Y., p. 1-84.

Forbes, S. A. 1907. On the local distribution of certain Illinois fishes: an essay in statistical ecology. Bul. Ill. State Lab. Nat. Hist., VII, (p. 273-303, Maps 1-15, Pl. XXIV-XXXII).

Huntsman, A. G. 1919. The vertical distribution of certain intertidal animals. Proc. and Trans. Roy. Soc. Canada, XII, 4, p. 53-60.

King, L. A. L., and Russell, E. S. 1909. A method for the study of the animal ecology of the shore. Proc. Roy. Phys. Soc. Edinburgh, XVII, p. 225-253.

Michael, E. L. 1920. Marine ecology and the coefficient of association; a plea in behalf of quantitative biology. Journ. Ecology, VIII, p. 54-59.

Packard, E. L. 1918. A quantitative analysis of the molluscan fauna of San Francisco Bay. Univ. Cal. Publ. Zool. XVIII, p. 299-308, 317-336, pls. XII and XIII.

Pearse, A. S. 1926. Animal ecology. McGraw-Hill, N. Y., p. 138-157.

Pratt, H. S. 1916. A manual of the common invertebrate animals. McClurg, p. 492-602.

Rogers, J. 1908. The Shell Book. Doubleday, Page & Co., p. 1-485.

Simroth, H. 1898-1907. Mollusca, Bronn's Klassen und Ordnungen des Tier-Reichs. III, 2, p. 769-771.

Sumner, F. B., Osburn, R., and Cole, L. J. 1913. A biological survey of the waters of Wood's Hole and vicinity. Bul. Bur. Fisheries, XXXI, I, Physical and Zoological, p. 143-155, 170-192, 327-330, 340-406, 429-441.

Verrill, A. E. 1873. Report upon the invertebrate animals of Vineyard Sound and adjacent waters. Rep. U. S. Fish. Comm., 1871-72, p. 295-513. Plates.